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Trends in the prevalence of diarrhea among children in the Democratic Republic of Congo (DRC). What is the source of changes?

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Objectives: To analyze trends in diarrhea prevalence by age, province and household living conditions; and to identify the sources of variation by child age, province of residence and household living conditions in the Democratic Republic of Congo (DRC).

Design: Cross-sectional.

Setting: The Democratic Republic of Congo (DRC).

Participants: 24,149 children under the age of five years from three databases. The databases contain information on 4,903 children from the 1995 Multiple Indicators Cluster Survey, 10,254 children from the 2001 Multiple Indicators Cluster Survey and 8,992 children from the 2007 Demographic and Health Survey.

Interventions: N/A

Primary and secondary outcome measures: whether the child had diarrhea 14 days preceding the survey.

Results: Overall, the proportion of under-five children who had suffered from diarrhea decreased by 27 percent from 22.2 percent in 1995 and 2001 to 16.4 percent in 2007. However, trends in diarrhea prevalence in the DRC from 1995 to 2007 present an inconsistent pattern. Depending on demographic, socioeconomic or geographic location, the proportion of children with diarrhea in the two weeks preceding the survey decreases or increases with a U shape association.

Findings from the decomposition analyses suggested that the decrease in diarrhea prevalence in the DRC between 1995 and 2007 or from 2001 to 2007 is not due to the change in the proportion of under-five children by age, living condition or province of residence. The apparent decline in diarrhea prevalence could be partly attributed to the seasonal pattern of the disease and/or to data quality.

Conclusion: Childhood diarrhea remains a public health problem in the DRC. Our study suggests that improvement of environmental sanitation and home hygiene, population health education and hygiene promotion programmes and raising the socioeconomic status of the population will contribute to the reduction of the higher diarrhea prevalence observed.

Introduction

Diarrheal disease is the second leading cause of death among children under five globally. About 22 percent of childhood deaths in developing countries are attributable to diarrhea.[1-3] It kills more young children than AIDS, malaria, and measles combined.[3]

Diarrheal diseases are associated with poverty and unhygienic environments.[4, 5] This probably explains the high prevalence of diarrhea in developing countries particularly in sub-Saharan Africa (SSA) and South Asia.[3]

With 89,900 annual child deaths due to diarrhea, the Democratic Republic of Congo (DRC) is the country with the third highest diarrheal morbidity among under-five children worldwide.[3] Three factors may explain this higher prevalence: the humanitarian crisis, environmental degradation and population poverty. Since 1996, the DRC has been hit by conflict, which has devastated and destabilized the country. People continue to live in crisis conditions in many parts of the country. The eastern provinces (Orientale, Katanga, Maniema, Nord Kivu and Sud Kivu), and more recently the province of Equateur, are afflicted by violence. The majority of people do not have access to clean drinking water (54 percent) and hygienic toilets (77 percent). Large amounts of faecal waste are also regularly discharged into the environment without adequate treatment.[6] Moreover, the DRC's 2010 Human Development Index (HDI) is estimated at 0.239, which gives the country a rank of 168 out of 169 countries with comparable data despite numerous natural resources.[7]

Yet, except for some descriptive survey reports[8-10], few systematic studies of trends and factors that influence the prevalence of diarrhea among young children in the DRC are carried out. However, there is need for rigorous studies for the correct understanding of the trends and sources of the observed changes as well as socioeconomic, environmental and cultural factors that determine the occurrence of diseases and deaths.

Against this background, this study aims to analyze diarrhea prevalence by age, province and household living conditions. The study will also identify the sources of diarrhea prevalence variation in DRC by child age, province of residence and household living conditions. The study relies on data from the three nationally representative surveys: the 1995 and 2001 MICS data and the 2007 DHS data.

1. Data and Methods

1.1. Variables

The vast majority of diarrhea is caused by infectious pathogens, although some diarrheas are due to errors of metabolism, chemical irritation or organic disturbance.[11] Human faeces are the primary source of diarrheal pathogens. The pathogen agents (viruses, bacteria, protozoa and parasitic worms) pass through the environment to reach new hosts. For children, the principal victims of diarrheal disease, 'the environment' is likely to be the home and its immediate vicinity.

Therefore, exposure to diarrhea-causing agents is frequently related to the use of contaminated water and to unhygienic practices in food preparation and disposal of excreta. Poor sanitation, lack of access to clean water and inadequate personal hygiene are responsible for an estimated 90 percent of childhood diarrhea. [3,6]

A large body of empirical work has shown an association between these variables and the prevalence of diarrhea among under-five children.[3,6,11-16] They have identified three variables that directly or indirectly determine diarrhea prevalence among children: child's age, access to clean water and sanitation and place of residence.

1.2. Data

This study uses three successive nationallly representative household surveys: the 1995 and 2001 MICS and the 2007 DHS. These surveys were carried out during three important periods of the DRC's political history: the transition towards democracy under Mobutu (1990-1997), the civil war and second transitional period (1996-2003), and after the 2006 multi-party elections. They are nationally representative of children's and women's health. They offer opportunity to analyze change in the diarrhea prevalence in the DRC. The three datasets have comparable information on household characteristics and child diarrhea at the time of the survey. The sample design and questionnaire are described elsewhere. [8-10]

The samples covered all provinces, urban and rural areas. Furthermore, the three surveys use multistage cluster-sampling. At the first stage, a stratified sample of enumeration areas (villages/communities) is taken; at the second stage, a sample of households within the selected communities is taken; and finally, at the third stage, all women respondents (aged 15-49 years) in the sample households are included. Cluster sampling is a cost-saving measure, without the need to list all the households. In total the 1995 MICS covers 4,574 households. The 2001 MICS covers a total of 8,600, whereas the 2007 DHS sample size is estimated at 8,886 households.

We define clean water or drinking water as water of sufficiently high quality that can be consumed or used with low risk of immediate or long-term harm. It is drawn from the tap (in the residence, in the plot, public tap…). The following methods are considered as developed sanitation services: public sewer, septic tank, pour-flush latrine, pit latrine with slab,

ventilated improved pit and ecological sanitation.[17] The MICS and DHS surveys collect these variables.

Table 1 presents the distribution of children by sex, age, place of residence and province in each survey.

Table 1 – Background characteristics of under-five children in DRC (1995, 2001 and 2007)

	1995 MICS		2001 MICS		2007 DHS	
	Percent	Number	Percent	Number	Percent	Number
Child sex						
Male	51.1	2,506	50.0	5,129	49.8	4,476
Female	48.9	2,397	50.0	5,125	50.2	4,516
Child age in months						
0-5 months	11.9	585	10.7	1,087	10.9	979
6-11 months	12.2	596	11.0	1,118	10.4	931
12-23 months	21.3	1,042	21.9	2,224	20.4	1,838
24-35 months	20.3	996	19.3	1,964	19.7	1,771
36-47 months	17.8	872	18.1	1,846	19.5	1,757
48-59 months	16.6	812	19.1	1,939	19.1	1,716
Place of residence						
Urban	31.8	1,558	36.0	3,695	39.8	3,575
Rural	68.2	3,345	64.0	6,559	60.2	5,417
Province of residence						
Kinshasa	4.4	215	14.4	1,473	10.2	914
Bas-Congo	10.3	504	5.3	542	7.3	659
Bandundu	11.4	557	11.7	1,198	9.1	819
Equateur	21.8	1,068	11.3	1,160	10.0	900
Orientale	8.8	432	10.2	1,041	7.2	644
Nord – Kivu	3.8	184	7.2	740	8.3	750
Maniema	10.8	531	2.6	262	9.5	855
Sud-Kivu	5.5	269	6.0	617	9.0	806
Katanga	2.5	123	11.2	1,149	9.8	878
Kasai Oriental	5.3	262	10.9	1,114	10.6	950
Kasai Occidental	15.5	758	9.3	958	9.1	817
Total	100.0	4,903	100.0	10,254	100.0	8,992

Source : 1995 DRC-MICS ; 2001DRC- MICS ; 2007 DRC-DHS

The database contains information on 4,903 children from the 1995 MICS, 10,254 children from the 2001 MICS and 8,992 children from the 2007 DHS. The distribution of under-five children by sex shows a generally similar pattern. Males and females are equally represented in the 3 surveys. With reference to the distribution by age, the proportion of children age less than 6 months seems to be similar (about 11 percent) in the three surveys, whereas small variations are observed in other age groups.

The proportion of children in urban areas increased from 32 percent in 1995 to 40 percent in 2007. Within the 11 provinces in DRC, the largest proportion of under-five children varies across surveys. In 1995, Equateur province was over represented with 21 percent, whereas in

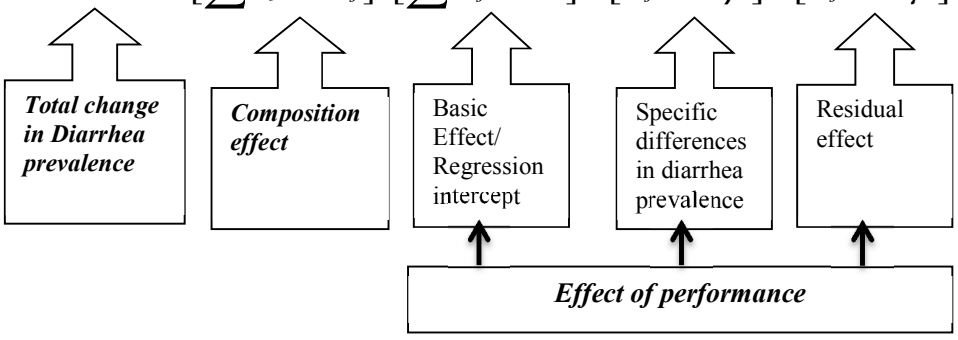
2001 the largest proportion of children is from Kinshasa (14 percent). The distribution of children by province in the 2007 DHS is more balanced.

2.1 Statistical methods

This study relies on three complementary methods: descriptive, decomposition and longitudinal multivariate models (fixed effect regression models). Descriptive analysis allows comparison of diarrhea prevalence by exposure variables (child' age, province of residence, household living conditions) over time.

The decomposition approach divides the trends in child's diarrhea prevalence into change in population composition and change in environmental sanitation and home hygiene from the first and the last survey.[18-19] This method assumes that the historical change in child diarrhea prevalence depends on: (1) Trends in distribution of under-five children by age, province of residence, household living conditions over time (composition effect); (2) Overall change in diarrhea prevalence among children age less than 5 years old or the basic effect that is the regression intercept when x=0 (α); (3) Variation of diarrhea prevalence by age, province of residence, household living conditions, groups measuring the changes in diarrhea prevalence associated with a unit variation in the distribution of under-five children by age, province of residence, household living conditions (β), and the residual effect of other variables not considered as e error term (μ). This change can be presented as follow:

$$\Delta D = [\sum \bar{d}_j * \Delta w_j] + [\sum \bar{w}_j * \Delta \alpha] + [w_j * x\Delta\beta] + [w_j * x\Delta\mu]$$



Four reasons justify the choice of the decomposition analysis: (1) the paper aims to analyze diarrhea prevalence change in the DRC; (2) the outcome variable (proportion of children who have suffered from diarrhea two weeks prior to the survey) is numerical; (3) the exposure variables (age, living conditions, province of residence) are ordinal level variables. It is important to clarify that provinces of residence are ranged according to their human development index (See Table A1 in annex); and (4) analyses are performed at aggregated/ cluster level (child age, household living conditions, province of residence). Furthermore, the decomposition method is simple, easy to apply and the results easy to interpret. In this way, we are able to describe trends in diarrhea prevalence by exposure variables and clearly identify the source of changes in diarrhea prevalence.

Finally, we use a fixed-effect (FE) regression model to explore the relationship between female education and modern contraceptive use within the country. The equation for the fixed effects model is displayed below:

$$Y_{it} = \beta_1 X_{it} + \alpha_i + \mu i_t$$

Where:

- α_i (i=1...n) is the unknown intercept for each entity (n entity-specific intercepts);
- Y_{it} is the dependent variable (diarrhea prevalence) where i=children and t=time;
- X_{it} represents the independent variable (child' age, province of residence, household living conditions);
- β_1 is the coefficient for the independent variable (child' age, province of residence, household living conditions);
- μ_1 is the error term.

3 Results

3.1 Trends in diarrhea prevalence in the DRC

Table 2 describes trends in diarrhea prevalence in the DRC from 1995 to 2007. In general, the prevalence of diarrhea in the DRC declined by 27 percent from 22 percent in 1995 and 2001 to 16 percent in 2007. There is no change in diarrhea prevalence between 1995 and 2001. However, analysis by child age, household living conditions and province of residence reveals diverse patterns of diarrhea prevalence in the DRC.

With reference to child age, there are two patterns in the different diarrhea prevalence trends.

- 0-23 months: The proportion of children who suffered from diarrhea increased between 1995 and 2001, and declined from 2001 to 2007 for children aged less than 24 months. This is a reversed U pattern.
- 24-59 months: The prevalence of diarrhea is declining. The magnitude of change is higher between 2001 and 2007 regardless of child age.

Moreover, prevalence of diarrhea is higher among children aged 6-11 months and 12-23 months than those belonging to other age groups.

In terms of household living conditions, trends in diarrhea prevalence could be divided into three groups.

- There is no change in diarrhea prevalence among children living in poorest households from 1995 to 2001. However diarrhea prevalence decreases by 27 percent within this group from 1995 to 2007 as well as between 2001 and 2007.
- The preceding pattern contrasts with that of children living in the most equipped households (with access to clean water and modern toilet). The proportion of children with diarrhea increased by 13.3 percent from 15.2 percent in 1995 to 17.2 percent in 2001. There are no significant differences in diarrhea prevalence between 1995 (17.2 percent) and 2007 (17.4 percent) in this category.

- There is also a continuous decline in diarrhea prevalence among children living in households with clean water or hygienic sanitation.

While in 1995 and 2001, the proportion of children with diarrhea was low among those living in better households, the opposite pattern is observed in 2007.

Table 2 – Prevalence of diarrhea among under-five children in DRC, 1995-2007

	Year			Percentage changes		
Background variables	1995	2001	2007	1995-2001	2001-2007	1995-2007
	1	2	3	4	5	6
Age in months						
0-5	12.7	15.3	10.5	20.7	-31.4	-17.2
6-11	33.4	36.0	28.6	7.7	-20.4	-14.3
12-23	33.9	34.7	26.1	2.4	-24.8	-23.0
24-35	22.4	21.7	17.1	-3.1	-21.3	-23.7
36-47	15.4	14.6	10.0	-5.2	-31.2	-34.7
48-59	11.6	10.7	6.8	-7.3	-36.3	-41.0
Living conditions						
No clean water or hygienic toilet	22.8	22.7	16.7	-0.1	-26.8	-26.8
One (hygienic toilet or water)	22.6	20.8	15.2	-8.0	-27.0	-32.8
Hygienic toilet and clean water	15.2	17.2	17.4	13.3	1.1	14.6
Province						
Kinshasa	13.5	20.9	13.4	54.9	-35.9	-0.7
Bas-Congo	12.5	19.4	10.9	55.2	-43.8	-12.7
Bandundu	17.7	14.6	11.4	-17.5	-22.1	-35.8
Equateur	26.4	27.3	14.1	3.4	-48.5	-46.7
Orientale	22.0	21.5	15.6	-2.3	-27.3	-29.0
Nord-Kivu	12.0	18.8	17.8	57.2	-5.4	48.7
Maniema	36.0	22.9	16.6	-36.3	-27.7	-54.0
Sud-Kivu	16.0	24.1	16.6	50.7	-31.0	4.1
Katanga	27.9	24.3	15.4	-12.9	-36.5	-44.7
Kasai-Oriental	13.4	27.2	23.2	103.6	-14.7	73.7
Kasai-Occidental	26.9	29.6	24.0	10.0	-19.1	-11.0
Total (DRC)	22.2	22.2	16.4	0.0	-26.1	-26.1

Source : 1995 DRC-MICS ; 2001DRC- MICS ; 2007 DRC-DHS

The diarrhea prevalence trends by province of residence show three patterns:

- In 7 provinces, including Kinshasa, the capital city, Bas-Congo, the poorer province of Equateur, the conflict related provinces (Nord and Sud-Kivu) and the mining provinces (Kasai Oriental and Kasai Occidental), diarrhea prevalence increased from 1995 to 2001 and declined between 2001 and 2007.
- Diarrhea prevalence is declining in the remaining 4 provinces (province of Katanga, Bandundu, Oriental and Maniema).

In summary, trends in diarrhea prevalence in the DRC from 1995 to 2007 present an inconsistent pattern. Depending on demographic, socioeconomic or geographic location, the proportion of children with diarrhea in the two weeks preceding the survey decreases or increases with a U shape association.

Decomposition of diarrhea prevalence changes in the DRC

We decompose changes in diarrhea prevalence by child's age, province of residence and household living condition. This may contribute to the understanding on how the observed changes relate to variations in the survey population structure or to changes in the environmental sanitation and home hygiene. Table 3 presents results of simple and advanced decomposition for the 1995-2007 period.

Table 3 : Decomposition of trends in diarrhea prevalence in the DRC 1995-2007

Age in months	Performance effect				Effect of Composition	Category Contribution
	Base	Differentiation	Error	Total		
	B1	B2	B3	B	A	C
0-5	-0.474	0.000	0.227	-0.248	-0.120	6.2%
6-11	-0.468	-0.039	-0.030	-1.624	-0.561	18.6%
12-23	-0.866	-0.144	-0.613	-1.062	-0.243	31.6%
24-35	-0.831	-0.208	-0.023	-0.846	-0.120	20.0%
36-47	-0.776	-0.259	0.038	-0.537	0.222	13.1%
48-59	-0.741	-0.309	0.203	-0.997	0.232	10.4%
Overall	70.4%	16.2%	3.4%	90.0%	10.0%	100.0%
Province						
Equateur	-1.526	0.137	-0.724	-2.113	-1.880	66.8%
Orientale	-0.898	0.161	0.093	-0.643	0.480	2.7%
Sud-Kivu	-0.455	0.123	0.366	0.033	-0.122	1.5%
Nord-Kivu	-0.346	0.124	0.449	0.226	0.042	-4.5%
Maniema	-0.628	0.282	-1.023	-1.369	-1.985	56.2%
Bandundu	-1.219	0.656	-0.303	-0.866	0.676	3.2%
Kasai-Occidental	-1.169	0.734	0.048	-0.387	-1.185	26.3%
Katanga	-0.546	0.392	-0.610	-0.764	1.569	-13.5%
Kasai-Oriental	-0.835	0.674	1.085	0.924	1.477	-40.2%
Bas-Congo	-0.636	0.570	-0.048	-0.114	-0.735	14.2%
Kinshasa	-0.646	0.638	0.002	-0.007	0.772	-12.8%
Overall	149.1%	-75.2%	11.1%	85.1%	14.9%	100.0%
Sanitation						
None	-6.031	0.000	1.386	-4.644	0.059	79.0%
Toilet or water	-1.447	0.759	-0.665	-1.354	0.403	16.4%
Toilet and water	-0.456	0.478	0.105	0.127	-0.396	4.6%
Overall	136.7%	-21.3%	-14.2%	101.2%	-1.2%	100%

Source : 1995 DRC-MICS ; 2007 DRC-DHS

In general, decomposition results indicate that changes in environmental sanitation and home hygiene is the principal source of change in diarrhea prevalence between 1995 and 2007 regardless of the exposure variable (Table 3, Column B). The analysis of performance effect (Table 3, columns B1 – B3) reveals the importance of the base effect. In other words, the observed changes are due to the general improvement in environmental sanitation and home hygiene in DRC. The differentiation effect, the error terms and the composition effect are negligible.

Table 3, Column C shows also that decline in diarrhea prevalence observed in 2007 compared to 1995 is mainly due to the low prevalence of diarrhea among children:

- aged 12-23 months,
- living in Equateur and Maniema province, and
- living in poor conditions (no clean water and hygienic sanitation).

By contrast, children living in Katanga, Kasai Oriental and Kinshasa contributed in the opposite direction (higher diarrhea prevalence).

Table 4 displays decomposition analysis findings for the period between 2001 and 2007. Like for the 1995-2007 period, decreases in diarrhea prevalence from 2001 to 2007 is attributable to the change in environmental sanitation and home hygiene. Overall the likelihood of having diarrhea decreased in the DRC regardless of child age, province of residence or the household living conditions.

Table 4: Decomposition of trends in diarrhea prevalence in the DRC 2001-2007

	Performance effect				Effect of	
Age in months	Base	Differentiation	Error	Total	Composition	Contribution
0-5	-0.737	0.000	0.221	-0.517	0.027	8.2%
6-11	-0.729	0.051	-0.105	-1.823	-0.203	16.5%
12-23	-1.446	0.204	-0.581	-0.899	-0.429	37.7%
24-35	-1.333	0.282	0.153	-0.744	0.078	13.8%
36-47	-1.288	0.363	0.070	-0.783	0.172	11.4%
48-59	-1.304	0.459	0.101	-0.855	0.003	12.4%
Overall	114.5%	-22.8%	2.4%	94.1%	5.9%	100.0%
Province						
Equateur	-0.540	0.009	-0.454	-0.985	2.087	-18.3%
Orientale	-0.895	0.031	0.139	-0.725	-0.360	18.0%
Sud-Kivu	-0.441	0.023	-0.035	-0.453	-0.542	16.5%
Nord-Kivu	-0.422	0.029	0.334	-0.059	-0.653	11.8%
Maniema	-0.220	0.019	0.009	-0.193	0.093	1.7%
Bandundu	-1.064	0.109	0.481	-0.473	0.352	2.0%
Kasai-Occidental	-0.784	0.094	0.081	-0.609	0.000	10.1%
Katanga	-0.916	0.125	-0.329	-1.120	-1.142	37.5%
Kasai-Oriental	-0.857	0.132	0.254	-0.471	0.812	-5.6%
Bas-Congo	-0.396	0.068	-0.135	-0.463	-0.439	14.9%
Kinshasa	-0.723	0.136	-0.160	-0.747	0.057	11.4%
Overall	120.3%	-12.8%	-3.1%	104.4%	-4.4%	100.0%
Sanitation						
None	-5.590	0.000	0.711	-4.879	-1.560	110.7%
Toilet or clean water	-1.026	0.462	-0.261	-0.825	1.658	-14.3%
Toilet and water	-0.361	0.325	0.046	0.010	-0.223	3.7%
Overall	119.9%	-13.5%	-8.5%	97.9%	2.1%	100.0%

Source : 2001DRC- MICS ; 2007 DRC-DHS

Children aged 12-23 months, those living in Katanga province and children living in poorer conditions contributed more in a diarrhea prevalence decline. The opposite contribution (increased diarrhea prevalence) is observed from children living in Equateur province and in Kasai Oriental.

3.3 Fixed effects of trends in proportion of child' age, province of residence and household's living condition on trends in prevalence of diarrhea in DRC

Table 5 displays results from fixed effects models. Overall there are no significant changes in diarrhea prevalence associated with variation of the population structure by age as well as by province and by household living conditions.

Table 5– Fixed effect of changes in proportion of children by selected characteristics on changes in diarrhea prevalence in DRC

	β	Constant	Sigma_u	Sigma_e	rho
Change in proportion of children per age	0.014	19.855	9.964	3.457	0.892
Change in proportion of children per province	0.2463	17.572	4.198	5.645	0.356
Change in proportion of children per household living conditions	-0.0612	20.999	4.334	3.381	0.622

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note : *** p<0.01 ; ** p<0.05 ; * p<0.1

However differences across years explain 89 percent of the variance in the distribution by age, 62 percent if one considers under-five children's distribution by province of residence. Changes in the proportion of population by household living conditions explain only 35 percent of the diarrhea variance.

Furthermore, findings show a lower diarrhea prevalence in 2007 compared to the other year (Table 6).

Table 6– Fixed effect of changes in proportion of children by selected characteristics and year of survey on changes in diarrhea prevalence in DRC

	Child age	Province	Living conditions
Proportion of children	-0.02	0.25	-0.06
1995	Ref	Ref	Ref
2001	0.60	2.39	0.03
2007	-5.05**	-4.12	-3.80
Const.	21.93*	18.15	22.30

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note: *** p<0.01 ; ** p<0.05 ; * p<0.1

Discussion and Conclusion

This study had twofold objectives. The first was to describe diarrhea prevalence trends in the DRC, and the second was to identify sources of observed changes in diarrhea prevalence. Exposure variables include child age, province of residence and the household living conditions. Using data from the DRC three nationally representative surveys: 1995 and 2001 MICS data and the 2007 DHS data, statistical methods include trend analysis, decomposition analysis and Fixed Effect regression models.

Overall, the proportion of under-five children who had suffered from diarrhea decreased by 27 percent from 22.2 percent in 1995 and 2001 to 16.4 percent in 2007. Though existing studies have shown a significant association between diarrheal diseases and child's age.[16,20-22] Depending on the context, scholars found that the prevalence of diarrhea is higher among children aged 6-12 months, 10-25 months or 12 - 36 months. In the DRC, Kandala[16] et al. 2009 found a positive association between child age and prevalence of diarrhea until 15 months of age and negative after. Child's age influences diarrhea through feeding practices, time to weaning, time to complementary food and sanitary conditions. Further children of crawling and walking age are vulnerable because they are more likely to play with, come in contact with or/and to eat faecally contaminated earth.

Likewise, improved household sanitation and water supply are expected to be the key factors associated with the decline of diarrheal disease in the long term. Sanitation and water supply have a direct effect in reducing exposure to pathogens. Previous studies have found that certain aspects of sanitation and water supply, such as the quantity of water available and whether the water was supplied inside or away from the home, are more important than other

aspects, such as water quality.[3,6,13,14,] Indirect effects may occur as the increased diffusion of sanitation and water supply in a community changes standard household hygienic practices. Consequently changes in the proportion of children with access to clean water and hygienic sanitation influences the diarrhea prevalence.

We assessed whether changes in the distribution of under-five children by age, household living conditions and province of residence may affect a variation of diarrhea prevalence over time. Findings are inconsistent:

- We observed no change in the diarrhea prevalence between 1995 and 2001, in contrast with a decrease in the diarrhea prevalence from 2001 to 2007 for some categories regardless of the independent variables;
- The proportion of children with diarrhea increased between 1995 and 2001 contrasting with stagnation observed between 2001 and 2007 in certain groups of children;
- There was an inverse U shape pattern in diarrhea prevalence among some children, whereas some children experienced a continuous decline in diarrhea prevalence.

Findings from the decomposition analyses (simple and advanced) suggested that a decrease in diarrhea prevalence in the DRC between 1995 and 2007 or from 2001 to 2007 is due to the change in environmental sanitation and home hygiene. This finding raises one fundamental question. *Did the environmental sanitation and home hygiene improve in the DRC between 1995 or 2001 and 2007?* It appears that the proportion of children living in households with access to clean water and hygienic sanitation diminished from 10.1 percent in 1995 to 5.9 percent in 2007 through 7.5 percent in 2001. The decline in diarrhea prevalence contrasts with an increase in the proportion of children living in households without access to safe water and sanitation. *What could explain this contrast (a decrease in diarrhea prevalence in the face of deterioration of living conditions)?* There are two hypotheses.

Firstly, do health education and hygiene promotion programmes, particularly the use of boiled drinking water, use of safe disposal of faecal material and the adequate washing of hands after contact with adult and child stools improve in the DRC? According to WHO & UNICEF (2010), large amounts of faecal waste are discharged into the environment without adequate treatment. Therefore, it is unlikely that the change could be attributable to improved sanitation. Secondly, are changes in the diarrhea prevalence affected by a seasonal effect? This is likely the main explanation of trends in diarrhea prevalence in the DRC between 1995 and 2007. The seasonal pattern of diarrheal disease gives a hint of pathogen multiplication in food. The peak of bacterial diarrheal disease is in the hottest and rainy season. One explanation for this could be that pathogenic bacteria can multiply more readily on stored food in warmer temperatures.[23,24]

The 1995 and 2001 MICS were carried out during the hot and rainy season (March-May) when diarrhea prevalence is higher; whereas the 2007 DHS data were collected during the dry season (June-August). Consequently we could partly attribute the contrast between decrease in diarrhea prevalence and stall in under-five mortality in the DRC from 1995 to 2007 to the seasonality of diarrhea diseases.

There may be also some issues with data quality. The prevalence of diarrhea increased among children living in households with clean water and toilet and decreased in those with worse household conditions (Figure 1).

[Figure 1, about here]

In conclusion, childhood diarrhea remains a public health problem in the DRC. The apparent decline in diarrhea prevalence could be partly attributable to the seasonal pattern of the disease. Our study suggests that improvement of environmental sanitation and home hygiene through population health education and hygiene promotion programmes, and raising the socioeconomic status of the population will contribute to the reduction of the higher diarrhea prevalence observed. This needs a concentrated effort from the Government because the country remains among the ten lowest-ranked nations in the 2011 GPI (148th of 153 countries, compared with 140th of 149 nations in the 2010 GPI) (Institute for Economics & Peace, 2011). In addition, the human development Index (HDI) for Sub-Saharan Africa as a region increased from 0.293 in 1980 to 0.389 in 2010, the DRC's HDI declined by -0.4% annually from 0.267 to 0.239. This gives the country a rank of 168th out of 169 countries with comparable data. [7]

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Competing Interest Statement

- there are no competing interests.

Contributorship Statement

- J BO E: Conception and design. Literature review. Data analysis and interpretation. Drafting the article. Critical revisions for important intellectual content. Approval of final article for submission.
  KN-B : Conception and design. Interpretation of results. Critical revisions for important intellectual content. Approval of final article for submission.

Data Sharing Statement

- none applicable. All data used are on the public domain

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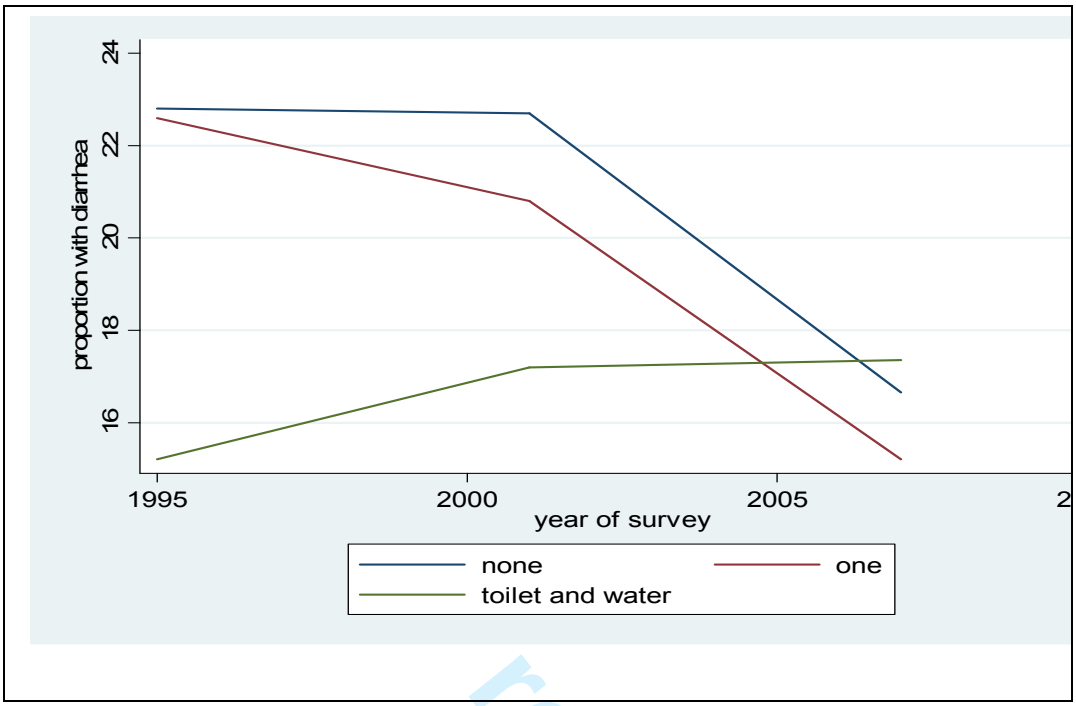
Competing interests: The authors declare that they have no competing interests'

Appendix **1**

Table A1: The DRC : Human Development Index by province in 2001

Rank	Province	HDI
1	Equateur	0.3090
2	Orientale	0.3520
3	Sud-Kivu	0.3730
4	Nord-Kivu	0.3800
5	Maniema	0.4190
6	Bandundu	0.4230
7	Kasai-Occidental	0.4290
8	Katanga	0.4350
9	Kasai-Oriental	0.4560
10	Bas-Congo	0.4650
11	Kinshasa	0.6200
Source : Congo, R. D., & USAID, U. &. (2002)		

Figure 1 – Diarrhea prevalence by household living conditions from 1995 to 2007



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	2, 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5,6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	*7,15*
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	2, 5,6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	13-14
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6
		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11, 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15, 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	NA

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Accounting for recent trends in the prevalence of diarrhea in the Democratic Republic of Congo (DRC)

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Accounting for recent trends in the prevalence of diarrhea in the Democratic Republic of Congo (DRC)

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Objectives: To analyze trends in diarrhea prevalence by maternal education, access to clean water and improved sanitation, household wealth index; to identify the sources of variation, and assess contribution of changes in socioeconomic characteristics in the DRC.

Design: Consecutive cross-sectional surveys.

Setting: DRC.

Participants: The databases contain information on 9,748 children from the 2001 Multiple Indicators Cluster Survey and 7987 children from the 2007 Demographic and Health Survey.

Interventions: N/A

Primary and secondary outcome measures: whether the child had diarrhea 14 days preceding the survey.

Results:

The Overall prevalence of diarrhea decreased by 26 percent (from 22.1 percent in 2001 to 16.4 percent in 2007). Findings from the three complementary statistical methods are consistent and confirm a significant decrease in diarrhea regardless of socioeconomic characteristics. Changes in behavior and/or in public health policy seem to be the likely main source of the change. There were no significant changes in diarrhea prevalence associated with variation of the population structure.

It is worth mentioning that the decrease in diarrhea prevalence contrasts with the generalized poor living conditions of the population. Therefore, it is difficult to ascertain whether the decline in diarrhea prevalence was due to real improvement in public health policy or to data quality issues.

Conclusion:

The decline of diarrhea prevalence in our study need to be further investigated by conducting district or provincial based studies to validate findings from household surveys such as DHS and MICS taking into account the current context of the country: ongoing conflict, poor socioeconomic and poor health infrastructure. However, improvement in living conditions such as access to clean water and improved sanitation will contribute to accelerate the reduction of diarrhea prevalence as well as reduction of child mortality.

Introduction

Diarrheal disease is the second leading cause of death among children under five globally. About 22 percent of childhood deaths in developing countries are attributable to diarrhea [1,2,3]. It kills more young children than AIDS, malaria, and measles combined [3].

Diarrheal diseases are associated with poverty and unhygienic environments [3,4,5]. This probably explains the high prevalence of diarrhea among children whose mothers did not attend school and/or among children living in poorest households particularly in sub-Saharan Africa and South Asia [3].

With about 1 percent of the global population, the Democratic Republic of Congo (DRC) has the third highest diarrheal morbidity among under-five children and the 5th highest under-five mortality rate worldwide [3,6]. About 13 percent of child deaths are diarrhea related, approximately 60,450 deaths due to diarrhea in 2010 [7].

However, recent data from national reports show a decrease in childhood diarrhea prevalence from 2001 to 2010. The prevalence of children with diarrhea decreased from 22 percent in 2001 [8] to around 17 percent in 2007 and 2010 [9,10].

Intuitively, the decrease in prevalence of diarrhea could be explained by: (1) public health improvement globally or selectively among some specific households; and/or (2) increase in the proportion of children living in households with access to water, sanitation and hygiene (wealthy household, living in urban areas, whose mothers have secondary education or higher). The question of substantive interest in this context is: how much of the change is actually due to the improvement of public health suggesting the actual decrease in diarrhea prevalence and how much is due to a compositional change in the population distribution, especially by maternal education, access to clean water and sanitation, household wealth index?

Against this background, this study aims to analyze diarrhea prevalence by maternal education, access to clean water and improved sanitation and household wealth index. The study will also identify the sources of variation of diarrhea prevalence in the DRC, and assess the contribution of each factor in the decline of diarrhea prevalence. To our knowledge, this is the first study of its kind in the DRC as only some descriptive survey reports [11, 8, 9, 10], and few systematic studies have analyzed trends and factors that influence the prevalence of diarrhea among young children in the DRC [12].

Data and Methods

Data

This study uses two successive nationally representative household surveys: the 2001 MICS and the 2007 DHS. During the 2001 Multiple Indicators Cluster Survey (MICS) data collection from May 21 to August 28, 2001, 3 provinces were entirely under the control of the government (Kinshasa, Bas-Congo and Bandundu), 4 were partially administrated by rebels (Equateur, Katanga, Kasai-Oriental and Kasai Occidental), and 4 were entirely controlled by rebels (Oriental, Nord Kivu, Sud Kivu and Maniema). Though the 2007 DHS was carried out after the 2006 elections (February 2 to April 30, 2007 for Kinshasa, and from May 10 to August 31, 2007 for the remaining provinces), some villages and municipalities in the Eastern provinces of Nord-Kivu, Sud-Kivu and Oriental were under armed conflict.

The two datasets have comparable information on household characteristics and child diarrhea at the time of the survey. The sample design and questionnaire are described elsewhere [8, 9]. Consequently, the two surveys offer the opportunity of analyzing change in diarrhea prevalence in the DRC. In total the 2001 MICS database includes information about 8,600 households and 9,748 under-five children, whereas the 2007 DHS database had information about 8,886 households and 7,987 children.

For each child under the age of five, the survey respondent in the household was asked whether the child has had diarrhea in the past two weeks prior to the surveys as indicated in the box below and in French language.

Box 1 – Question on diarrhea among under-five children

1. 2001 MICS: [(*Nom de l'enfant*) a-t-il/elle eu la diarrhée au cours des 2 dernières semaines, c'est-à-dire, depuis (*jour de la semaine*) de l'avant dernière semaine ? in French]. *Has (name of the child) had diarrhea in the last two weeks, that is, since (day of the week) of the week before last*
2. 2007 DHS:[(Nom de l'enfant) a eu la diarrhée au cours des deux dernières semaines? In French] "*Has (name of the child) had diarrhea in the past 2 weeks?*"

Therefore, diarrhea is determined not by medical examination but it is self-reported by the mother or caretaker with symptoms of three or more loose or watery stools per day, or blood in stool.

Variables

Exposure to diarrhea-causing agents is frequently related to the use of contaminated water and to unhygienic practices in food preparation and disposal of excreta. Poor sanitation, lack of access to clean water and inadequate personal hygiene are responsible for an estimated 90 percent of childhood diarrhea [3, 4,5,13].

Exposure variables for this study include maternal education, access to clean water and sanitation, and household wealth index. A large body of empirical work has shown association between these variables and the prevalence of diarrhea among under-five children [3,12, 13, 14,15, 16, 17, 18].

We define clean water or drinking water as water of sufficiently high quality that can be consumed or used with low risk of immediate or long-term harm. It is drawn from an improved drinking water source protected from outside contamination, in particular from contamination with fecal matter including piped water (into residence or plot),

public tap, tube well, protected dug wells and protected springs [19,20]. An improved sanitation facility is defined as one that is likely to hygienically separate human excreta from human contact: public sewer, septic tank, pour-flush latrine, pit latrine with slab, ventilated improved pit and ecological sanitation [19,20]. The MICS and DHS surveys collecting these variables use the same definition and categorization [21,22].

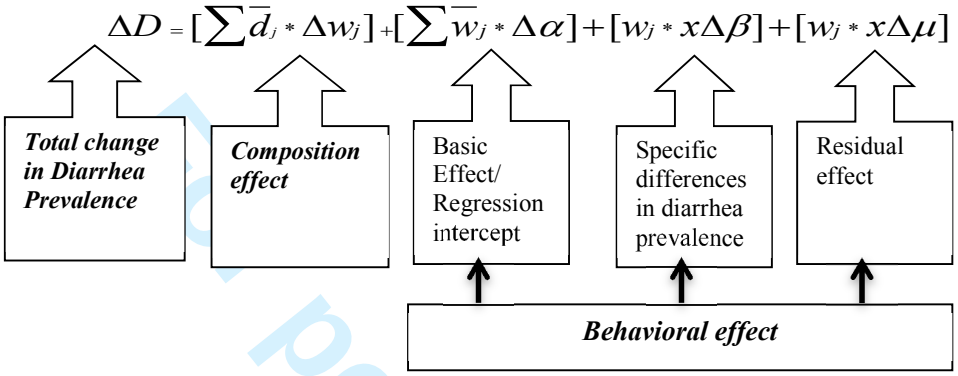
In this study, household wealth index is measured with an asset index and wealth quintile constructed using the statistical Procedure Principal Component Analysis (PCA) developed by Filmer and Pritchett [23]. The index measures economic status based on housing characteristics, household assets and possession of household consumer durables as well as access to clean water and improved sanitation. The 2001 MICS and 2007 DHS have collected these data. Using rank methods, households are classified by quintile of wealth.

Statistical methods

This study uses three complementary methods: trends analysis, decomposition and longitudinal multivariate models (fixed effect regression models). The Stata,"**nptrend**" command performs a non-parametric test of trend for the ranks across ordered groups. The test is an extension of the Wilcoxon rank-sum test [24]. The test provides Z statistics and P-value showing whether the change is statistically significant or not.

The decomposition approach divides the trends in child's diarrhea prevalence into change in population structure and change in health behavior and/or public health over the study period [25,26]. This method assumes that the historical change in child diarrhea prevalence depends on: (1) Trends in distribution of under-five children by access to clean water and improved sanitation facility, household wealth index and maternal education over time (composition effect); (2) actual change in diarrhea prevalence due to change in health behavior or

improvement in public health (the basic effect) that is the regression intercept when x=0 (α); (3) Variation of diarrhea prevalence by exposure variables (β), and the residual effect of other variables not considered as e error term (μ). This change can be presented as follow:



The decomposition analyses are performed at aggregated/ cluster level (the national level by maternal education and household living conditions).

Finally, we use a fixed-effect (FE) regression model to explore the relationship between female education and modern contraceptive use within the country. The equation for the fixed effects model is displayed below:

$$Y_{it} = \beta_1 X_{it} + \alpha_i + \mu i_t$$

Where:

- α_i (i=1...n) is the unknown intercept for each entity (n entity-specific intercepts);
- Y_{it} is the dependent variable (diarrhea prevalence) where i=children and t=time;
- X_{it} represents the independent variable (child' age, province of residence, household living conditions);
- β_1 is the coefficient for the independent variable (maternal education, access to clean water and sanitation, and household wealth index.);
- μ_1 is the error term.

To perform the fixed effect models, we constructed three independent panel datasets (Maternal education, Access to clean water and improved sanitation and household wealth index). Each dataset has multiple observations about each category of the independent

variable considered as individual (number of surveys, 2 in our case). Therefore, the maternal education database contains six observations, while numbers of observations for the access to clean water and improved sanitation and the household wealth index database are respectively estimated at 8 and 10 observations; each database contains the following information proportion of under-five children, year of survey and diarrhea prevalence.

Results

Sample description

Table 1 presents the distribution of under-five children by selected background characteristics in each sample.

Table 1 – Background characteristics of under-five children in DRC (2001 and 2007)

	2001 MICS		2007 DHS	
	Percent	Number	Percent	Number
Child sex				
Male	49.8	4,855	49.5	3,956
Female	50.2	4,893	50.5	4,031
Child age in months				
0-5 months	11.1	1,070	11.5	919
6-11 months	11.3	1,090	10.8	865
12-23 months	22.3	2,162	20.4	1,632
24-35 months	19.2	1,864	19.8	1,582
36-47 months	17.6	1,709	19.0	1,519
48-59 months	18.5	1,792	18.4	1,470
Access to clean water and sanitation				
None	11.8	1,153	13.0	1,039
Water only	6.7	654	1.4	111
Toilet only	41.1	4,008	57.6	4,604
Water and toilet	40.4	3,933	28.0	2,233
Place of residence				
Urban	35.4	3,446	41.1	3,282
Rural	64.6	6,302	58.9	4,705
Province of residence				
Kinshasa	13.9	1,352	10.7	852
Bas-Congo	5.3	515	7.4	590
Bandundu	11.9	1,162	9.2	734
Equateur	11.4	1,107	9.9	789
Orientale	10.0	974	7.1	567
Nord – Kivu	7.3	708	8.7	691
Maniema	6.1	593	9.2	736
Sud-Kivu	2.6	253	8.9	710
Katanga	11.3	1,100	9.6	766
Kasai Oriental	10.9	1,058	10.3	826
Kasai Occidental	9.5	926	9.1	726
Maternal education				
None	27.5	2,680	23.9	1,909
Primary	41.2	4,015	42.2	3,369
Secondary and high	31.3	3,053	33.9	2,709
Household Wealth Index				
Poorest	20.0	1,953	22.0	1,759
Second	19.5	1,903	20.2	1,609
Middle	19.6	1,911	19.5	1,555

Fourth	19.3	1,877	20.9	1,669
Richest	21.6	2,104	17.5	1,395
Total	100.0	9,748	100.0	7,987

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note : Sometime N < Total due to missing values

The database contains information on 9,748 children from the 2001 MICS and 7,987 children from the 2007 DHS. The characteristics of under-five children shown in Table 1, reveal differences in structure across surveys except if one considers child' age and sex. For instance, the proportion of children living in households with access to clean water and to toilets decreased from 40 percent in 2001 to 28 percent in 2007. Moreover, the proportion of under-five children by province of residence varies across surveys. In 2001, the largest proportion of children sample was from Kinshasa (14 percent) and in 2007 a large proportion of children came from Kasai Oriental and Kinshasa.

Trends in diarrhea prevalence in the DRC

Table 2 describes trends in diarrhea prevalence in the DRC from 2001 to 2007.

Table 2 – Prevalence of diarrhea among under-five children in DRC, 1995-2007

	Year		Variation (%)	NPTREND TEST	
Background variables	2001	2007	2001-2007	Z	P-value
	1	2	3		0.000
Maternal education					
None	22.5	15.8	-30.0	-4.24	0.000
Primary	22.9	18.9	-17.4	-5.29	0.000
Secondary &+	20.8	13.9	-33.4	-7.50	0.000
Water and sanitation					
None	25.8	18.2	-29.3	-4.14	0.000
Water alone	23.4	19.5	-16.8	-1.46	0.143
Toilet alone	21.4	16.2	-24.2	-5.96	0.000
Water and toilet	21.6	15.9	-26.7	-6.46	0.000
Household wealth index					
Poorest	20.8	17.0	-18.2	-2.12	0.030
Second	24.9	15.7	-37.0	-6.08	0.000
Middle	23.4	16.2	-30.6	-5.65	0.000
Fourth	23.3	18.3	-21.5	-4.82	0.000
Richest	18.7	14.4	-22.8	-3.99	0.000
Total (DRC)	22.1	16.4	-25.8	-9.74	0.000

Source : 2001DRC- MICS ; 2007 DRC-DHS
Variation (3)=((Prevalence in 2007/ Prevalence in 2001)-(1))*100

There is a decrease in the prevalence of diarrhea. Overall, the prevalence of diarrhea in the DRC declined by 26 percent (Z=-9.7, P-value<0.000) from 22 percent in 2001 to 16 percent in 2007. However, this decrease in diarrhea prevalence is not statistically significant among children who reside in households with water alone without toilet (Z=-1.46, P-value=0.143).

Decomposition of diarrhea prevalence changes in the DRC

We decompose changes in diarrhea prevalence by maternal education, housing living conditions and household wealth index. This may contribute to the understanding on how the observed changes relate to variations in the survey population structure or to changes in public health and/or changes in behavior. Table 3 presents results of the decomposition analysis.

Table 3: Decomposition of trends in diarrhea prevalence in the DRC 2001-2007

	Behavioral effect				Effect of	
	Base	Differentiation	Error	Total	Composition	Contribution
	B1	B2	B3	B	A	C
Maternal education						
None	-1.422	0.000	-0.243	-1.665	-0.764	43.4%
Primary	-2.317	-0.079	0.792	-1.604	0.149	26.0%
Secondary &+	-1.837	-0.125	-0.314	-2.277	0.566	30.6%
Overall	99.7%	3.6%	-4.2%	99.1%	0.9%	100.0
Water and sanitation						
None	-0.732	0.000	-0.349	-1.081	-0.447	27.3%
Water alone	-0.108	0.007	0.087	-0.014	-0.526	9.7%
Toilet alone	-3.201	0.438	-0.580	-3.343	0.945	42.8%
Water and toilet	-1.149	0.236	-0.169	-1.082	-0.050	20.2%
Overall	92.7%	-12.2%	18.0%	98.6%	1.4%	100.0
Household wealth index						
Poorest	-1.425	0.064	0.588	-0.773	0.499	4.9%
Second	-1.340	0.120	-0.605	-1.825	0.226	28.6%
Middle	-1.302	0.176	-0.245	-1.371	-0.038	25.2%
Fourth	-1.337	0.240	0.109	-0.988	0.323	11.9%
Richest	-1.270	0.286	0.185	-0.799	-0.845	29.4%
Overall	119.4%	-15.8%	-0.6%	103.0%	-3%	100.0

Source : 2001DRC- MICS ; 2007 DRC-DHS

In general, decomposition results indicate that changes in actual diarrhea prevalence and/or health behavior are the principal source of decline in diarrhea prevalence between 2001 and

2007 regardless of the exposure variable (Table 3, Column B). The analysis of behavioral effect (Table 3, columns B1 – B3) suggests that the observed decline in diarrhea prevalence is global (not specific to some socioeconomic characteristics). In other words, the observed changes are due to the general improvement in health behavior in the DRC. The differentiation effect, the error terms and the composition effect are negligible.

Table 3 (column C) shows also the contribution of each socioeconomic category in the overall decrease of diarrhea prevalence in the DRC between 2001 and 2007. Depending on the independent variable, decline in diarrhea prevalence in the following groups have contributed more to the observed changes: Children whose mothers did not attend school (43 percent), among children who live in household with toilet but without access to clean water (43 percent) and among children living in the richest households (29 percent) and children living in the poorer households (29 percent) have contributed more to the diarrhea decrease in the DRC between 2001 and 2007. By contrast, small contributions to the overall changes in diarrhea prevalence are observed from children living in household with "water alone without toilet" (10 percent) and from children who stay in poorest households (5 percent).

Fixed effects of trends in proportion of child's age, province of residence and household's living condition on trends in prevalence of diarrhea in DRC

Table 4 displays results from fixed effects models. Overall there are no significant changes in diarrhea prevalence associated with a variation of the population structure by maternal education, household access to clean water and sanitation as well as by household wealth index.

Table 4– Fixed effect of changes in proportion of children by selected characteristics on

changes in diarrhea prevalence in DRC

	β	Constant	Sigma_u	Sigma_e	rho
Change in proportion of children per maternal education	-0.1052	15.626	1.478	5.203	0.070
Change in proportion of children per living condition (access to clean water and sanitation)	-0.008	20.446	1.573	4.699	0.101
Change in proportion of children per household wealth index	-0.1546	22.363	1.691	4.922	0.106

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note : *** p<0.01 ; ** p<0.05 ; * p<0.1

However differences across years explain 7 percent of the variance in the distribution by maternal education, and about 10 percent if one considers under-five children's distribution by access to water and toilet and household wealth index respectively.

Discussion and Conclusion

This study had threefold objective. The first was to describe diarrhea prevalence trends in the DRC, the second was to identify sources of observed changes in diarrhea prevalence, and the last was to assess the contribution of different categories to the observed changes. Exposure variables included maternal education, access to clean water and improved sanitation, and household wealth index. The study used data from the DRC 2001 MICS and 2007 DHS surveys.

Findings from the three complementary statistical methods (trend analysis, decomposition analysis and Fixed Effect regression models) are consistent. The significant decrease in diarrhea prevalence observed in the DRC between 2001 and 2007 is regardless of socioeconomic characteristic and the results from trend analysis corroborate the absence of a composition effect revealed by the decomposition as well as no significant changes in diarrhea prevalence associated with variation of the population structure (results from the Fixed Effect regression models). Likewise, these results support the decrease in under-five

mortality observed in the country since 2001: 213 per thousand live births in 2001 [8] and 158 per thousand live births in 2010 [10].

Furthermore, children of mothers who never attended school, those living in households with toilet alone (without water), and children living in the poorer (second quintile) households as well as those living in the richest households have contributed more than other children to the observed decline in diarrhea prevalence.

However, the decrease in diarrhoea prevalence in the DRC as well as the decline in child mortality contrast with the generalized humanitarian crisis, deterioration in environmental conditions and population poverty observed in the country in the same study period. The country is among the lowest-ranked nations in the 2011 Global Peace Index (148th of 153 countries) [27]. Since 1996, the DRC has been hit by conflict, which has devastated and destabilized the country. People continue to live in crisis conditions in many parts of the country. The eastern provinces (Orientale, Katanga, Maniema, Nord Kivu and Sud Kivu) are afflicted by violence.

Moreover, the DRC's 2010 Human Development Index (HDI) is estimated at 0.239, which gives the country a rank of 168 out of 169 countries with comparable data despite numerous natural resources [28]. Overall, the majority of people do not have access to clean drinking water (54 percent) and improved sanitation (77 percent) [13]. With reference to data used in this study, the proportion of children living in households with access to clean water and improved sanitation diminished from 40 percent in 2001 to 28 percent in 2007.

Two hypotheses could explain the observed discrepancies between the living conditions and changes in diarrhea prevalence in the DRC. Firstly, there may be some real improvement in health behavior, particularly the use of boiled drinking water and the adequate washing of

hands after contact with adult and child stools. However, we cannot test such hypothesis because of lack of data.

Secondly, there may be some issues with data quality. In conflict situations, it might be very difficult to collect reliable data. For instance, during the 2001 MICS, in the Eastern part, often interviewers had to stop their work and resume after several days. Rebels arrested a fieldworker for more than six weeks (MICS2) [8]. Furthermore, diarrhea prevalence is based on self-reporting. Mothers or caregivers can mis-declare diarrhoea prevalence according to her understanding of diarrhea definition in the local language. Also, duration of data collection varies considerably by province (1 month in Kinshasa and about 2 months in Nord-Kivu and Katanga for the 2001 MICS). In addition, the distribution of children by some socioeconomic characteristics varies across survey. This is probably due to the use of an old national sampling frame from the 1984 Census. However, the methods used (decomposition and fixed effect regression models) control for variation in proportion during analyses.

In conclusion, childhood diarrhea remains a public health problem in the DRC despite the observed decline. It is noteworthy that the overall significant decrease in diarrhea prevalence in the DRC contrasts with the poor living conditions observed in the same period. Our study suggests further studies at the district or province levels to validate findings from national household surveys such as DHS and MICS considering the conflict context of the country when these data were collected and the continuing degradation of the country's socioeconomic and transport infrastructure and security. We hope that the next census in preparation will provide a more comprehensive sampling frame. However, improvement in access to clean water and improved sanitation will contribute to accelerate reduction of diarrhea prevalence as well as reduction of child mortality.

ARTICLE SUMMARY

Article focus

- With about 1 percent of the global population, the Democratic Republic of Congo (DRC) has the third highest diarrheal morbidity among under-five children and the 5th highest under-five mortality rate worldwide. Recent national surveys reports show a decrease in childhood diarrhea prevalence from 22 percent in 2001 to 16 percent in 2007.
- Intuitively, the decrease in prevalence of diarrhea could be explained by: (1) public health improvement nationally or selectively among some specific households; and/or (2) increase in the proportion of children living in households with access to water, sanitation and hygiene. We apply appropriate statistical techniques (decomposition analysis and fixed effect regression models) to describe trends in diarrhea prevalence, identify the actual sources of changes and assess the contribution of selected factors in the observed changes.
- We use data from two consecutive nationally representative household surveys to investigate trends in diarrhea in the DRC.

Key messages

- Our results provide evidence of a significant decrease in diarrhea prevalence regardless of socioeconomic characteristics considered.
- The findings indicate that changes in behavior and/or in public health policy seem to be the likely main source of the observed changes. There were no significant changes in diarrhea prevalence associated with variation of the population structure.
- However, childhood diarrhea remains a very important public health issue in the DRC despite the observed decline.
- Moreover, the observed diarrhea prevalence contrasts with the poor living conditions and high mortality observed in the same period.
- Therefore, further studies at the district or provincial level are needed to validate our findings. These studies should take into account the current context of the country: ongoing conflict, poor socioeconomic and lack of access to health infrastructures, and poor health infrastructure.

Strengths and limitations of this study

- This is the first study of its kind in the DRC that describe trends, identify sources of changes and assess factors contributing to the changes in diarrhea prevalence among under-five children using two national representative surveys. Furthermore, we used robust statistical techniques to assess changes. The study combines three complementary statistics techniques (trends analysis, decomposition and fixed effect regression models).
- The major limitation of this study is potential data quality issues since data were collected in the conflict and post conflict contexts. Indeed, the significant observed decrease in diarrhea prevalence in the DRC contrasts with the generalized poor living conditions of the population.

- Another limitation of the study is the way diarrhea was ascertained. It is self-reported and not determined by a medical examination of trained medical staff. Therefore, the respondent may be subjected to recall bias or mis-interpretation of symptoms.

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KN-B : Conception and design. Interpretation of results. Critical revisions for important intellectual content. Approval of final article for submission.

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Accounting for recent trends in the prevalence of diarrhea in the Democratic Republic of Congo (DRC)

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Objectives: To analyze trends in diarrhea prevalence by maternal education, access to clean water and improved sanitation, household wealth index; to identify the sources of variation, and assess contribution of changes in socioeconomic characteristics in the DRC.

Design: Consecutive cross-sectional surveys.

Setting: DRC.

Participants: The databases contain information on 9,748 children from the 2001 Multiple Indicators Cluster Survey and 7987 children from the 2007 Demographic and Health Survey.

Interventions: N/A

Primary and secondary outcome measures: whether the child had diarrhea 14 days preceding the survey.

Results:

The Overall prevalence of diarrhea decreased by 26 percent (from 22.1 percent in 2001 to 16.4 percent in 2007). Findings from the three complementary statistical methods are consistent and confirm a significant decrease in diarrhea regardless of socioeconomic characteristics. Changes in behavior and/or in public health policy seem to be the likely main source of the change. There were no significant changes in diarrhea prevalence associated with variation of the population structure.

It is worth mentioning that the decrease in diarrhea prevalence contrasts with the generalized poor living conditions of the population. Therefore, it is difficult to ascertain whether the decline in diarrhea prevalence was due to real improvement in public health policy or to data quality issues.

Conclusion:

The decline of diarrhea prevalence in our study need to be further investigated by conducting district or provincial based studies to validate findings from household surveys such as DHS and MICS taking into account the current context of the country: ongoing conflict, poor socioeconomic and poor health infrastructure. However, improvement in living conditions such as access to clean water and improved sanitation will contribute to accelerate the reduction of diarrhea prevalence as well as reduction of child mortality.

Introduction

Diarrheal disease is the second leading cause of death among children under five globally. About 22 percent of childhood deaths in developing countries are attributable to diarrhea [1,2,3]. It kills more young children than AIDS, malaria, and measles combined [3].

Diarrheal diseases are associated with poverty and unhygienic environments [3,4,5]. This probably explains the high prevalence of diarrhea among children whose mothers did not attend school and/or among children living in poorest households particularly in sub-Saharan Africa and South Asia [3].

With about 1 percent of the global population, the Democratic Republic of Congo (DRC) has the third highest diarrheal morbidity among under-five children and the 5th highest under-five mortality rate worldwide [3,6]. About 13 percent of child deaths are diarrhea related, approximately 60,450 deaths due to diarrhea in 2010 [7].

However, recent data from national reports show a decrease in childhood diarrhea prevalence from 2001 to 2010. The prevalence of children with diarrhea decreased from 22 percent in 2001 [8] to around 17 percent in 2007 and 2010 [9,10].

Intuitively, the decrease in prevalence of diarrhea could be explained by: (1) public health improvement globally or selectively among some specific households; and/or (2) increase in the proportion of children living in households with access to water, sanitation and hygiene (wealthy household, living in urban areas, whose mothers have secondary education or higher). The question of substantive interest in this context is: how much of the change is actually due to the improvement of public health suggesting the actual decrease in diarrhea prevalence and how much is due to a compositional change in the population distribution, especially by maternal education, access to clean water and sanitation, household wealth index?

Against this background, this study aims to analyze diarrhea prevalence by maternal education, access to clean water and improved sanitation and household wealth index. The study will also identify the sources of variation of diarrhea prevalence in the DRC, and assess the contribution of each factor in the decline of diarrhea prevalence. To our knowledge, this is the first study of its kind in the DRC as only some descriptive survey reports [11, 8, 9, 10], and few systematic studies have analyzed trends and factors that influence the prevalence of diarrhea among young children in the DRC [12].

Data and Methods

Data

This study uses two successive nationally representative household surveys: the 2001 MICS and the 2007 DHS. During the 2001 Multiple Indicators Cluster Survey (MICS) data collection from May 21 to August 28, 2001, 3 provinces were entirely under the control of the government (Kinshasa, Bas-Congo and Bandundu), 4 were partially administrated by rebels (Equateur, Katanga, Kasai-Oriental and Kasai Occidental), and 4 were entirely controlled by rebels (Oriental, Nord Kivu, Sud Kivu and Maniema). Though the 2007 DHS was carried out after the 2006 elections (February 2 to April 30, 2007 for Kinshasa, and from May 10 to August 31, 2007 for the remaining provinces), some villages and municipalities in the Eastern provinces of Nord-Kivu, Sud-Kivu and Oriental were under armed conflict.

The two datasets have comparable information on household characteristics and child diarrhea at the time of the survey. The sample design and questionnaire are described elsewhere [8, 9]. Consequently, the two surveys offer the opportunity of analyzing change in diarrhea prevalence in the DRC. In total the 2001 MICS database includes information about 8,600 households and 9,748 under-five children, whereas the 2007 DHS database had information about 8,886 households and 7,987 children.

For each child under the age of five, the survey respondent in the household was asked whether the child has had diarrhea in the past two weeks prior to the surveys as indicated in the box below and in French language.

Box 1 – Question on diarrhea among under-five children

1. 2001 MICS: [(*Nom de l'enfant*) a-t-il/elle eu la diarrhée au cours des 2 dernières semaines, c'est-à-dire, depuis (*jour de la semaine*) de l'avant dernière semaine ? in French]. *Has (name of the child) had diarrhea in the last two weeks, that is, since (day of the week) of the week before last*
2. 2007 DHS:[(Nom de l'enfant) a eu la diarrhée au cours des deux dernières semaines? In French] "*Has (name of the child) had diarrhea in the past 2 weeks?*"

Therefore, diarrhea is determined not by medical examination but it is self-reported by the mother or caretaker with symptoms of three or more loose or watery stools per day, or blood in stool.

Variables

Exposure to diarrhea-causing agents is frequently related to the use of contaminated water and to unhygienic practices in food preparation and disposal of excreta. Poor sanitation, lack of access to clean water and inadequate personal hygiene are responsible for an estimated 90 percent of childhood diarrhea [3, 4,5,13].

Exposure variables for this study include maternal education, access to clean water and sanitation, and household wealth index. A large body of empirical work has shown association between these variables and the prevalence of diarrhea among under-five children [3,12, 13, 14,15, 16, 17, 18].

We define clean water or drinking water as water of sufficiently high quality that can be consumed or used with low risk of immediate or long-term harm. It is drawn from an improved drinking water source protected from outside contamination, in particular from contamination with fecal matter including piped water (into residence or plot),

public tap, tube well, protected dug wells and protected springs [19,20]. An improved sanitation facility is defined as one that is likely to hygienically separate human excreta from human contact: public sewer, septic tank, pour-flush latrine, pit latrine with slab, ventilated improved pit and ecological sanitation [19,20]. The MICS and DHS surveys collecting these variables use the same definition and categorization [21,22].

In this study, household wealth index is measured with an asset index and wealth quintile constructed using the statistical Procedure Principal Component Analysis (PCA) developed by Filmer and Pritchett [23]. The index measures economic status based on housing characteristics, household assets and possession of household consumer durables as well as access to clean water and improved sanitation. The 2001 MICS and 2007 DHS have collected these data. Using rank methods, households are classified by quintile of wealth.

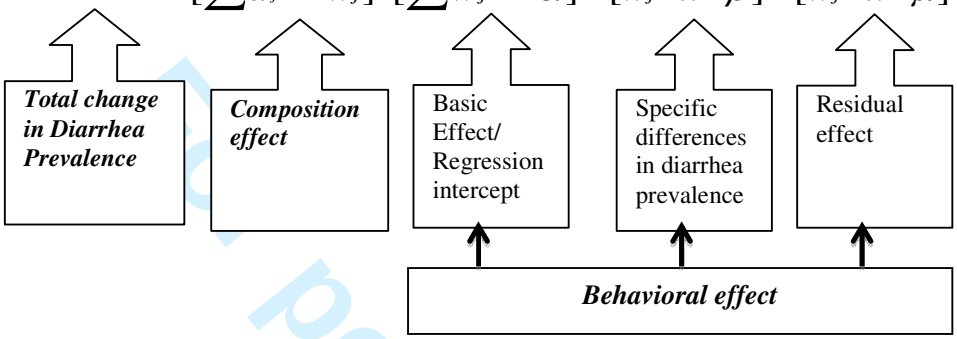
Statistical methods

This study uses three complementary methods: trends analysis, decomposition and longitudinal multivariate models (fixed effect regression models). The Stata,"**nptrend**" command performs a non-parametric test of trend for the ranks across ordered groups. The test is an extension of the Wilcoxon rank-sum test [24]. The test provides Z statistics and P-value showing whether the change is statistically significant or not.

The decomposition approach divides the trends in child's diarrhea prevalence into change in population structure and change in health behavior and/or public health over the study period [25,26]. This method assumes that the historical change in child diarrhea prevalence depends on: (1) Trends in distribution of under-five children by access to clean water and improved sanitation facility, household wealth index and maternal education over time (composition effect); (2) actual change in diarrhea prevalence due to change in health behavior or

improvement in public health (the basic effect) that is the regression intercept when x=0 (α); (3) Variation of diarrhea prevalence by exposure variables (β), and the residual effect of other variables not considered as e error term (μ). This change can be presented as follow:

$$\Delta D = [\sum \bar{d}_j * \Delta w_j] + [\sum \bar{w}_j * \Delta \alpha] + [w_j * x \Delta \beta] + [w_j * x \Delta \mu]$$



The decomposition analyses are performed at aggregated/ cluster level (the national level by maternal education and household living conditions).

Finally, we use a fixed-effect (FE) regression model to explore the relationship between female education and modern contraceptive use within the country. The equation for the fixed effects model is displayed below:

$$Y_{it} = \beta_1 X_{it} + \alpha_i + \mu i_t$$

Where:

- α_i (i=1...n) is the unknown intercept for each entity (n entity-specific intercepts);
- Y_{it} is the dependent variable (diarrhea prevalence) where i=children and t=time;
- X_{it} represents the independent variable (child' age, province of residence, household living conditions);
- β_1 is the coefficient for the independent variable (maternal education, access to clean water and sanitation, and household wealth index.);
- μ_1 is the error term.

To perform the fixed effect models, we constructed three independent panel datasets (Maternal education, Access to clean water and improved sanitation and household wealth index). Each dataset has multiple observations about each category of the independent

variable considered as individual (number of surveys, 2 in our case). Therefore, the maternal education database contains six observations, while numbers of observations for the access to clean water and improved sanitation and the household wealth index database are respectively estimated at 8 and 10 observations; each database contains the following information proportion of under-five children, year of survey and diarrhea prevalence.

Results

Sample description

Table 1 presents the distribution of under-five children by selected background characteristics in each sample.

Table 1 – Background characteristics of under-five children in DRC (2001 and 2007)

	2001 MICS		2007 DHS	
	Percent	Number	Percent	Number
Child sex				
Male	49.8	4,855	49.5	3,956
Female	50.2	4,893	50.5	4,031
Child age in months				
0-5 months	11.1	1,070	11.5	919
6-11 months	11.3	1,090	10.8	865
12-23 months	22.3	2,162	20.4	1,632
24-35 months	19.2	1,864	19.8	1,582
36-47 months	17.6	1,709	19.0	1,519
48-59 months	18.5	1,792	18.4	1,470
Access to clean water and sanitation				
None	11.8	1,153	13.0	1,039
Water only	6.7	654	1.4	111
Toilet only	41.1	4,008	57.6	4,604
Water and toilet	40.4	3,933	28.0	2,233
Place of residence				
Urban	35.4	3,446	41.1	3,282
Rural	64.6	6,302	58.9	4,705
Province of residence				
Kinshasa	13.9	1,352	10.7	852
Bas-Congo	5.3	515	7.4	590
Bandundu	11.9	1,162	9.2	734
Equateur	11.4	1,107	9.9	789
Orientale	10.0	974	7.1	567
Nord – Kivu	7.3	708	8.7	691
Maniema	6.1	593	9.2	736
Sud-Kivu	2.6	253	8.9	710
Katanga	11.3	1,100	9.6	766
Kasai Oriental	10.9	1,058	10.3	826
Kasai Occidental	9.5	926	9.1	726
Maternal education				
None	27.5	2,680	23.9	1,909
Primary	41.2	4,015	42.2	3,369
Secondary and high	31.3	3,053	33.9	2,709
Household Wealth Index				
Poorest	20.0	1,953	22.0	1,759
Second	19.5	1,903	20.2	1,609
Middle	19.6	1,911	19.5	1,555

Fourth	19.3	1,877	20.9	1,669
Richest	21.6	2,104	17.5	1,395
Total	100.0	9,748	100.0	7,987

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note : Sometime N < Total due to missing values

The database contains information on 9,748 children from the 2001 MICS and 7,987 children from the 2007 DHS. The characteristics of under-five children shown in Table 1, reveal differences in structure across surveys except if one considers child' age and sex. For instance, the proportion of children living in households with access to clean water and to toilets decreased from 40 percent in 2001 to 28 percent in 2007. Moreover, the proportion of under-five children by province of residence varies across surveys. In 2001, the largest proportion of children sample was from Kinshasa (14 percent) and in 2007 a large proportion of children came from Kasai Oriental and Kinshasa.

Trends in diarrhea prevalence in the DRC

Table 2 describes trends in diarrhea prevalence in the DRC from 2001 to 2007.

Table 2 – Prevalence of diarrhea among under-five children in DRC, 1995-2007

	Year		Variation (%)	NPTREND TEST	
Background variables	2001	2007	2001-2007	Z	P-value
	1	2	3		0.000
Maternal education					
None	22.5	15.8	-30.0	-4.24	0.000
Primary	22.9	18.9	-17.4	-5.29	0.000
Secondary &+	20.8	13.9	-33.4	-7.50	0.000
Water and sanitation					
None	25.8	18.2	-29.3	-4.14	0.000
Water alone	23.4	19.5	-16.8	-1.46	0.143
Toilet alone	21.4	16.2	-24.2	-5.96	0.000
Water and toilet	21.6	15.9	-26.7	-6.46	0.000
Household wealth index					
Poorest	20.8	17.0	-18.2	-2.12	0.030
Second	24.9	15.7	-37.0	-6.08	0.000
Middle	23.4	16.2	-30.6	-5.65	0.000
Fourth	23.3	18.3	-21.5	-4.82	0.000
Richest	18.7	14.4	-22.8	-3.99	0.000
Total (DRC)	22.1	16.4	-25.8	-9.74	0.000

Source : 2001DRC- MICS ; 2007 DRC-DHS
Variation (3)=((Prevalence in 2007/ Prevalence in 2001)-(1))*100

There is a decrease in the prevalence of diarrhea. Overall, the prevalence of diarrhea in the DRC declined by 26 percent (Z=-9.7, P-value<0.000) from 22 percent in 2001 to 16 percent in 2007. However, this decrease in diarrhea prevalence is not statistically significant among children who reside in households with water alone without toilet (Z=-1.46, P-value=0.143).

Decomposition of diarrhea prevalence changes in the DRC

We decompose changes in diarrhea prevalence by maternal education, housing living conditions and household wealth index. This may contribute to the understanding on how the observed changes relate to variations in the survey population structure or to changes in public health and/or changes in behavior. Table 3 presents results of the decomposition analysis.

Table 3: Decomposition of trends in diarrhea prevalence in the DRC 2001-2007

	Behavioral effect				Effect of	
	Base	Differentiation	Error	Total	Composition	Contribution
	B1	B2	B3	B	A	C
Maternal education						
None	-1.422	0.000	-0.243	-1.665	-0.764	43.4%
Primary	-2.317	-0.079	0.792	-1.604	0.149	26.0%
Secondary &+	-1.837	-0.125	-0.314	-2.277	0.566	30.6%
Overall	99.7%	3.6%	-4.2%	99.1%	0.9%	100.0
Water and sanitation						
None	-0.732	0.000	-0.349	-1.081	-0.447	27.3%
Water alone	-0.108	0.007	0.087	-0.014	-0.526	9.7%
Toilet alone	-3.201	0.438	-0.580	-3.343	0.945	42.8%
Water and toilet	-1.149	0.236	-0.169	-1.082	-0.050	20.2%
Overall	92.7%	-12.2%	18.0%	98.6%	1.4%	100.0
Household wealth index						
Poorest	-1.425	0.064	0.588	-0.773	0.499	4.9%
Second	-1.340	0.120	-0.605	-1.825	0.226	28.6%
Middle	-1.302	0.176	-0.245	-1.371	-0.038	25.2%
Fourth	-1.337	0.240	0.109	-0.988	0.323	11.9%
Richest	-1.270	0.286	0.185	-0.799	-0.845	29.4%
Overall	119.4%	-15.8%	-0.6%	103.0%	-3%	100.0

Source : 2001DRC- MICS ; 2007 DRC-DHS

In general, decomposition results indicate that changes in actual diarrhea prevalence and/or health behavior are the principal source of decline in diarrhea prevalence between 2001 and

2007 regardless of the exposure variable (Table 3, Column B). The analysis of behavioral effect (Table 3, columns B1 – B3) suggests that the observed decline in diarrhea prevalence is global (not specific to some socioeconomic characteristics). In other words, the observed changes are due to the general improvement in health behavior in the DRC. The differentiation effect, the error terms and the composition effect are negligible.

Table 3 (column C) shows also the contribution of each socioeconomic category in the overall decrease of diarrhea prevalence in the DRC between 2001 and 2007. Depending on the independent variable, decline in diarrhea prevalence in the following groups have contributed more to the observed changes: Children whose mothers did not attend school (43 percent), among children who live in household with toilet but without access to clean water (43 percent) and among children living in the richest households (29 percent) and children living in the poorer households (29 percent) have contributed more to the diarrhea decrease in the DRC between 2001 and 2007. By contrast, small contributions to the overall changes in diarrhea prevalence are observed from children living in household with "water alone without toilet" (10 percent) and from children who stay in poorest households (5 percent).

Fixed effects of trends in proportion of child's age, province of residence and household's living condition on trends in prevalence of diarrhea in DRC

Table 4 displays results from fixed effects models. Overall there are no significant changes in diarrhea prevalence associated with a variation of the population structure by maternal education, household access to clean water and sanitation as well as by household wealth index.

Table 4– Fixed effect of changes in proportion of children by selected characteristics on

changes in diarrhea prevalence in DRC

	β	Constant	Sigma_u	Sigma_e	rho
Change in proportion of children per maternal education	-0.1052	15.626	1.478	5.203	0.070
Change in proportion of children per living condition (access to clean water and sanitation)	-0.008	20.446	1.573	4.699	0.101
Change in proportion of children per household wealth index	-0.1546	22.363	1.691	4.922	0.106

Source : 2001DRC- MICS ; 2007 DRC-DHS
Note : *** p<0.01 ; ** p<0.05 ; * p<0.1

However differences across years explain 7 percent of the variance in the distribution by maternal education, and about 10 percent if one considers under-five children's distribution by access to water and toilet and household wealth index respectively.

Discussion and Conclusion

This study had threefold objective. The first was to describe diarrhea prevalence trends in the DRC, the second was to identify sources of observed changes in diarrhea prevalence, and the last was to assess the contribution of different categories to the observed changes. Exposure variables included maternal education, access to clean water and improved sanitation, and household wealth index. The study used data from the DRC 2001 MICS and 2007 DHS surveys.

Findings from the three complementary statistical methods (trend analysis, decomposition analysis and Fixed Effect regression models) are consistent. The significant decrease in diarrhea prevalence observed in the DRC between 2001 and 2007 is regardless of socioeconomic characteristic and the results from trend analysis corroborate the absence of a composition effect revealed by the decomposition as well as no significant changes in diarrhea prevalence associated with variation of the population structure (results from the Fixed Effect regression models). Likewise, these results support the decrease in under-five

mortality observed in the country since 2001: 213 per thousand live births in 2001 [8] and 158 per thousand live births in 2010 [10].

Furthermore, children of mothers who never attended school, those living in households with toilet alone (without water), and children living in the poorer (second quintile) households as well as those living in the richest households have contributed more than other children to the observed decline in diarrhea prevalence.

However, the decrease in diarrhoea prevalence in the DRC as well as the decline in child mortality contrast with the generalized humanitarian crisis, deterioration in environmental conditions and population poverty observed in the country in the same study period. The country is among the lowest-ranked nations in the 2011 Global Peace Index (148th of 153 countries) [27]. Since 1996, the DRC has been hit by conflict, which has devastated and destabilized the country. People continue to live in crisis conditions in many parts of the country. The eastern provinces (Orientale, Katanga, Maniema, Nord Kivu and Sud Kivu) are afflicted by violence.

Moreover, the DRC's 2010 Human Development Index (HDI) is estimated at 0.239, which gives the country a rank of 168 out of 169 countries with comparable data despite numerous natural resources [28]. Overall, the majority of people do not have access to clean drinking water (54 percent) and improved sanitation (77 percent) [13]. With reference to data used in this study, the proportion of children living in households with access to clean water and improved sanitation diminished from 40 percent in 2001 to 28 percent in 2007.

Two hypotheses could explain the observed discrepancies between the living conditions and changes in diarrhea prevalence in the DRC. Firstly, there may be some real improvement in health behavior, particularly the use of boiled drinking water and the adequate washing of

hands after contact with adult and child stools. However, we cannot test such hypothesis because of lack of data.

Secondly, there may be some issues with data quality. In conflict situations, it might be very difficult to collect reliable data. For instance, during the 2001 MICS, in the Eastern part, often interviewers had to stop their work and resume after several days. Rebels arrested a fieldworker for more than six weeks (MICS2) [8]. Furthermore, diarrhea prevalence is based on self-reporting. Mothers or caregivers can mis-declare diarrhoea prevalence according to her understanding of diarrhea definition in the local language. Also, duration of data collection varies considerably by province (1 month in Kinshasa and about 2 months in Nord-Kivu and Katanga for the 2001 MICS). In addition, the distribution of children by some socioeconomic characteristics varies across survey. This is probably due to the use of an old national sampling frame from the 1984 Census. However, the methods used (decomposition and fixed effect regression models) control for variation in proportion during analyses.

In conclusion, childhood diarrhea remains a public health problem in the DRC despite the observed decline. It is noteworthy that the overall significant decrease in diarrhea prevalence in the DRC contrasts with the poor living conditions observed in the same period. Our study suggests further studies at the district or province levels to validate findings from national household surveys such as DHS and MICS considering the conflict context of the country when these data were collected and the continuing degradation of the country's socioeconomic and transport infrastructure and security. We hope that the next census in preparation will provide a more comprehensive sampling frame. However, improvement in access to clean water and improved sanitation will contribute to accelerate reduction of diarrhea prevalence as well as reduction of child mortality.

Article focus

- With about 1 percent of the global population, the Democratic Republic of Congo (DRC) has the third highest diarrheal morbidity among under-five children and the 5th highest under-five mortality rate worldwide. Recent national surveys reports show a decrease in childhood diarrhea prevalence from 22 percent in 2001 to 16 percent in 2007.
- Intuitively, the decrease in prevalence of diarrhea could be explained by: (1) public health improvement nationally or selectively among some specific households; and/or (2) increase in the proportion of children living in households with access to water, sanitation and hygiene. We apply appropriate statistical techniques (decomposition analysis and fixed effect regression models) to describe trends in diarrhea prevalence, identify the actual sources of changes and assess the contribution of selected factors in the observed changes.
- We use data from two consecutive nationally representative household surveys to investigate trends in diarrhea in the DRC.

Key messages

- Our results provide evidence of a significant decrease in diarrhea prevalence regardless of socioeconomic characteristics considered.
- The findings indicate that changes in behavior and/or in public health policy seem to be the likely main source of the observed changes. There were no significant changes in diarrhea prevalence associated with variation of the population structure.
- However, childhood diarrhea remains a very important public health issue in the DRC despite the observed decline.
- Moreover, the observed diarrhea prevalence contrasts with the poor living conditions and high mortality observed in the same period.
- Therefore, further studies at the district or provincial level are needed to validate our findings. These studies should take into account the current context of the country: ongoing conflict, poor socioeconomic and lack of access to health infrastructures, and poor health infrastructure.

Strengths and limitations of this study

- This is the first study of its kind in the DRC that describe trends, identify sources of changes and assess factors contributing to the changes in diarrhea prevalence among under-five children using two national representative surveys. Furthermore, we used robust statistical techniques to assess changes. The study combines three complementary statistics techniques (trends analysis, decomposition and fixed effect regression models).
- The major limitation of this study is potential data quality issues since data were collected in the conflict and post conflict contexts. Indeed, the significant observed decrease in diarrhea prevalence in the DRC contrasts with the generalized poor living conditions of the population.
- Another limitation of the study is the way diarrhea was ascertained. It is self-reported and not determined by a medical examination of trained medical staff. Therefore, the respondent may be subjected to recall bias or mis-interpretation of symptoms.

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Competing interests: The authors declare that they have no competing interests

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	2, 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5,6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	*7,15*
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	2, 5,6
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	13-14
Outcome data	15*	Report numbers of outcome events or summary measures	11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6
		(*b*) Report category boundaries when continuous variables were categorized	6
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11, 15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15, 16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	NA

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.